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<p>(21) International Application Number: PCT/FI99/00582</p> <p>(22) International Filing Date: 30 June 1999 (30.06.99)</p> <p>(30) Priority Data: 981517 1 July 1998 (01.07.98) FI</p> <p>(71) Applicant (for all designated States except US): VALMET AUTOMATION INC. [FI/FI]; Panuntie 6, FIN-00620 Helsinki (FI).</p> <p>(72) Inventors; and (75) Inventors/Applicants (for US only): KOIVUKUNNAS, Pekka [FI/FI]; Kauhavankuja 5, FIN-04430 Järvenpää (FI). TORVI, Timo [FI/FI]; Wärtsiläkatu 76, FIN-04440 Järvenpää (FI).</p> <p>(74) Agent: KOLSTER OY AB; Iso Roobertinkatu 23, P.O. Box 148, FIN-00121 Helsinki (FI).</p>		<p>(81) Designated States: AE, AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published</p> <p><i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>	
<p>(54) Title: METHOD AND APPARATUS FOR MEASURING THE TENSION OF A MOVING WEB</p> <p>The diagram illustrates a cross-sectional view of a tension measuring apparatus. A web (1) is shown moving from left to right. It passes over a curved measuring beam (2). The space between the web and the beam is filled with air, forming an air cushion (3). The beam is supported by a base (4) which has two vertical supports (5) and a central sensor unit (6) connected to the beam.</p>			
<p>(57) Abstract</p> <p>The invention relates to a method and apparatus for measuring the tension of a moving web. In the invention, a measuring beam (2) is curved so that a web moving over or under the measuring beam (2) forms an air cushion (3) of the air it transports between the measuring beam (2) and the web (1). The web (1) causes a force effect transmitted by the air cushion on the measuring beam (2). The tension of the web (1) is measured by measuring the force caused by the web (1) and transmitted by the measuring beam (2).</p>			

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## METHOD AND APPARATUS FOR MEASURING THE TENSION OF A MOVING WEB

5 A method for measuring the tension of a moving web, in which method the moving web is directed over or under a curved measuring beam in such a way that the web forms an air cushion of the air it transports between the web and the measuring beam, whereby the web moves over the measuring beam on the air cushion causing a force effect transmitted by the air cushion on the measuring beam.

10 The invention further relates to an apparatus for measuring the tension of a moving web, which apparatus comprises a curved measuring beam so that the moving web directed over or under the measuring beam forms an air cushion of the air it transports between the web and the measuring beam and the web moving over the measuring beam on the air cushion causes a force effect transmitted by the air cushion on the measuring beam.

15 When manufacturing paper, the formed and ready paper web is rolled at several stages of the process. For instance, at the end of the process, the web is rolled into large rolls several metres in diameter. The tension of the rolls should remain the same both in the longitudinal direction of the web and in the vertical direction of the roll so as to make the paper behave in as similar a way as possible in the process of the end-user, for example a printing house, independent of what part of the roll the printed sheet has been taken from. In addition, when winding the web from one roll to another, the rotation speeds of the rolls and the torques winding the rolls need to be adjusted to be suitable in relation to each other, because when the diameter of the roll changes, also the circumferential speed of the roll changes. To be able to wind the web in a roll so that the tension of the web is suitable throughout the roll and to be able to wind the web from one roll to another without loosening or tightening the web too much and breaking it, the tension of the web must be measured during winding and the rotation speeds of the rolls adjusted according to the measured tension data. A tension measuring instrument also quickly indicates a break in the web.

30 Canadian Patent 1 265 940 discloses a solution for measuring web tension. In the solution, the web is brought in contact with a measuring element comprising several contiguous short rolls or several contiguous support elements including a flexible band. The load caused by the contact is

measured with sensors connected to the element and the tension of the web is determined from the load. The problem in this solution is that for measuring, the web must be bent over the measuring element so that it touches the element. This may damage the web. When using rolls, the increasing rotation speeds and the imbalance of the roll cause disturbances in the measuring signal.

European Patent publication 0 490 971 discloses a measuring process of web tension, in which the web is brought in contact with a measuring element comprising several contiguous short rolls. Drawbacks as described above are also present in this solution.

Finnish Patent 80 522 discloses a solution, in which the tension of a moving web is measured by placing close to the web in the direction of travel of the web a measuring beam provided with a curved surface and pressure measuring cells in the holes of the beam. An air cushion is formed between the web and the curved surface, in which air pressure is comparable to the tension of the web. The tension of the web is measured by measuring the pressure of this air cushion. The solution in question provides the advantage that the web is not damaged, as the measuring beam does not touch the web. On the whole, the solution is quite functional, but somewhat complicated in its measuring arrangement.

The object of the present invention is to provide a method and apparatus, in which said drawbacks can be avoided.

The method of the invention is characterized in that the tension of the web is measured by measuring the force resulting from the web and transmitted by the measuring beam.

Further, the apparatus of the invention is characterized in that the apparatus comprises means for measuring the force resulting from the web and transmitted by the measuring beam.

An essential idea of the invention is that the tension of a web is measured by arranging the web to travel over a measuring beam which has been arranged so that the web moves over the measuring beam on an air cushion formed when the air transported by the web is pressed between the measuring beam and the web. Further, it is essential that the force caused by the tension of the web on the measuring beam is measured by measuring the force effect transmitted onward by the beam. The idea of a preferred embodiment of the invention is that the force effect transmitted by the beam is

measured with weighing sensors arranged under the ends of the measuring beam. The idea of another preferred embodiment is that the force transmitted by the measuring beam is measured with strain gauges arranged on the beam.

5           The invention provides the advantage that as the web does not touch the measuring beam, the measuring of the tension does not damage or stress the web. The solution is also very simple in structure and measuring technique. On the whole, the adjustment accuracy of the drives and the runnability of the machine are extremely good and the number of breaks  
10       remains small.

          In this application, the term "web" refers, for instance, to a paper or board web.

          The invention will be described in greater detail in the attached drawing, in which

15           Figure 1 is a schematic side view and cross-section of a solution of the invention and

          Figure 2 shows the solution shown in Figure 1 viewed from the direction of travel of the web and in cross-section.

          Figure 1 shows a web 1 which moves in the direction of arrow A.  
20       The web 1 has been arranged to move over a measuring beam 2. The measuring beam is made of a wear-resistant material, such as aluminium, and extends preferably substantially uniformly across the entire web 1. The surface of the measuring beam 2 against the web 1 is curved. The surface can also be formed of a surface with two or more curvature centres, of some other suitable  
25       curved surface, or in such a way that the front edge of the measuring beam 2 is a straight line at a suitable angle in relation to the web 1 and the trailing edge of the measuring beam 2 is in the shape of a circular arc. Due to the curved form, the air transported by the web 1 is pressed between the measuring beam 2 and the web 1 in such a way that the web 1 moves over  
30       the measuring beam 2 on an air cushion 3. The radius of curvature of the surface of the measuring beam 2 against the web 1 can vary, for instance, between 20 cm and one metre.

          The pressure of the air cushion 3 between the web 1 and the measuring beam 2 corresponds in a balanced state quite accurately to the  
35       force caused by the tension of the web 1. The pressure of the air cushion 3 affects the measuring beam 2 and the force transmitted by the measuring

beam 2 can be measured, for instance as shown in Figure 2. With said measuring, it is possible to measure indirectly the tension of the web 1. The measuring beam 2 can be supported, for instance on its ends and weighing sensors 4 can be placed at the ends to measure the force transmitted by the measuring beam 2. Instead of or in addition to the weighing sensors 4, the force transmitted by the measuring beam 2 can be measured by placing one or more strain gauges 5 on the measuring beam 2 on the side not facing the web 1. To measure the force transmitted by the measuring beam 2, at least one strain gauge 5 placed at the point of maximum torque, i.e., in the mid-section of the measuring beam 2, is required. It is possible to increase the measuring accuracy and reliability by using several strain gauges 5. In this case, too, at least a part of the strain gauges 5 are preferably placed in the mid-section of the measuring beam. The signals produced by the weighing sensors 4 and/or the strain gauges 5 are directed to a control device 6 which defines the tension of the web 1 according to the received signals and forwards the information onward.

The drawing and the related description are only intended to illustrate the idea of the invention. The details of the invention may vary within the scope of the claims. Thus, for measurement of tension, the web 1 can also be directed under the measuring beam 2 comprising a suitably formed bottom surface.

## CLAIMS

1. A method for measuring the tension of a moving web, in which method the moving web (1) is directed over or under a curved measuring beam (2) in such a way that the web (1) forms an air cushion (3) of the air it transports between the web (1) and the measuring beam (2), whereby the web (1) moves over the measuring beam (2) on the air cushion (3) causing a force effect transmitted by the air cushion on the measuring beam (2), **characterized** in that the tension of the web (1) is measured by measuring the force resulting from the web (1) and transmitted by the measuring beam (2).

2. A method as claimed in claim 1, **characterized** in that the force transmitted by the measuring beam (2) is measured by measuring the force caused by the measuring beam (2) in the weighing sensors (4) under the measuring beam (2).

3. A method as claimed in claim 2, **characterized** in that the weighing sensors (4) are arranged at both ends of the measuring beam (2).

4. A method as claimed in claim 1, **characterized** in that the force transmitted by the measuring beam (2) is measured by at least one strain gauge (5) placed under the measuring beam (2).

5. A method as claimed in claim 4, **characterized** in that at least one strain gauge (5) is placed in the mid-section of the measuring beam (2).

6. An apparatus for measuring the tension of a moving web, which apparatus comprises a curved measuring beam (2) so that the moving web (1) directed over or under the measuring beam (2) forms an air cushion (3) of the air it transports between the web (1) and the measuring beam (2) and the web (1) moving over the measuring beam (2) on the air cushion (3) causes a force effect transmitted by the air cushion on the measuring beam (2), **characterized** in that the apparatus comprises means for measuring the force resulting from the web (1) and transmitted by the measuring beam (2).

7. An apparatus as claimed in claim 6, **characterized** in that the apparatus comprises weighing sensors (4) arranged under the measuring beam (2) for measuring the force transmitted by the measuring



beam.

8. An apparatus as claimed in claim 7, **characterized** in that the weighing sensors (4) are arranged at both ends of the measuring beam (2).

5        9. An apparatus as claimed in claim 6, **characterized** in that the apparatus comprises at least one strain gauge (5) arranged to measure the force transmitted by the measuring beam (2).

10       10. An apparatus as claimed in claim 9, **characterized** in that the measuring beam (2) comprises several strain gauges (5).

10       11. An apparatus as claimed in claim 9 or 10, **characterized** in that at least one strain gauge (5) is placed in the mid-section of the measuring beam (2).

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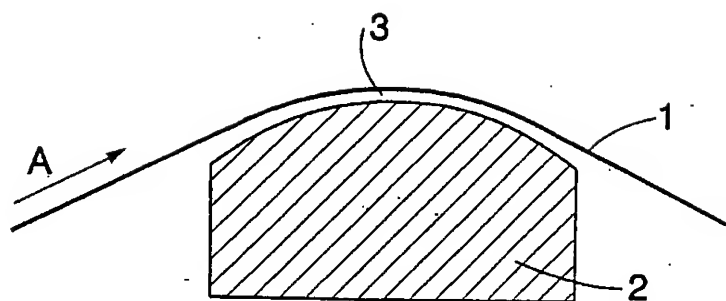


FIG. 1

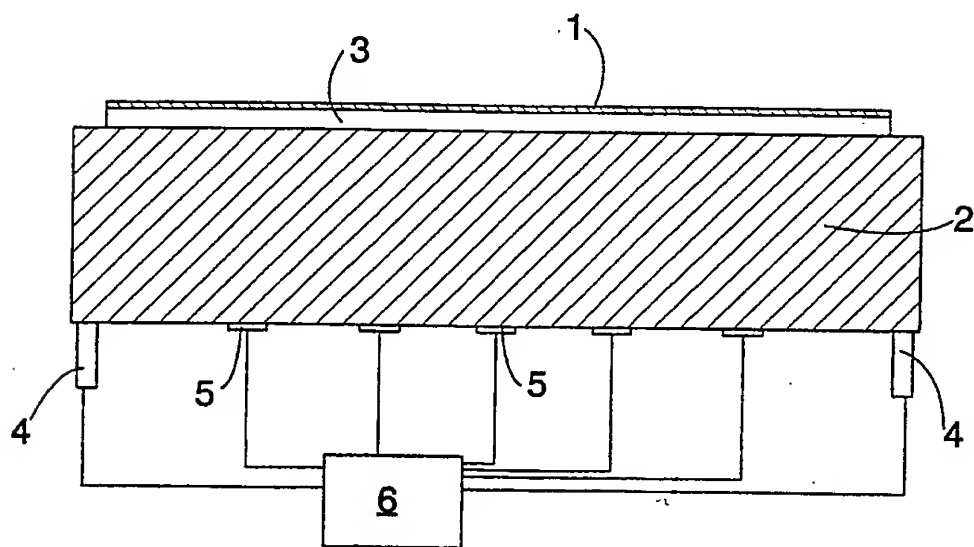


FIG. 2

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/FI 99/00582

## A. CLASSIFICATION OF SUBJECT MATTER

IPC6: G01L 5/04

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: G01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5052233 A (E. RANTALA), 1 October 1991 (01.10.91), abstract --	1-11
A	DE 4301618 A1 (SULZER-ESCHER WYSS GMBH); 5 May 1994 (05.05.94), abstract --	1-11
A	WO 9103600 A1 (DAVY MCKEE (POOLE) LIMITED), 21 March 1991 (21.03.91), abstract --	1-11
A	US 5301866 A (K. VEI ET AL.), 12 April 1994 (12.04.94), abstract --	1-11

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A	<p>US 4300714 A (CARL B. DAHL ET AL.),  17 November 1981 (17.11.81), abstract</p> <p style="text-align: center;">--  -----</p>	1-11

**INTERNATIONAL SEARCH REPORT**  
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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5052233 A	01/10/91	AT 99416 T CA 1321893 A DE 68911862 D,T EP 0367901 A,B SE 0367901 T3 ES 2048240 T FI 80522 B,C FI 884236 D JP 2114141 A JP 2644047 B PT 91706 A,B	15/01/94 07/09/93 19/05/94 16/05/90  16/03/94 28/02/90 00/00/00 26/04/90 25/08/97 30/03/90
DE 4301618 A1	05/05/94	NONE	
WO 9103600 A1	21/03/91	CA 2066232 A DE 69017219 D,T EP 0490971 A,B SE 0490971 T3 FI 920952 D JP 5500089 T US 5298121 A	10/10/90 22/06/95 24/06/92  00/00/00 14/01/93 29/03/94
US 5301866 A	12/04/94	DE 4134590 A,C DE 59206107 D EP 0538672 A,B SE 0538672 T3 JP 5215669 A	22/04/93 00/00/00 28/04/93  24/08/93
US 4300714 A	17/11/81	CA 1131557 A EP 0032875 A,B SE 0032875 T3 FI 810111 A GB 2070570 A,B JP 56103047 A	14/09/82 29/07/81  18/07/81 09/09/81 17/08/81